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Designing Collaboration Tools to Optimize Distributed Battlespace Synchronization

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14. ABSTRACT

Military organizations rely on teams to accomplish complex task objectives. One way to promote team effectiveness is through team training such as cross-training. The current study investigated the influence of cross-training on performance and team process factors (collective efficacy, communication, cohesion, and team trust). Thirty participants engaged in a command and control air defense simulation and team process measures were assessed across four days of data collection. Cross-training influenced trust but not as expected. Individuals on cross-trained teams reported lower trust over time relative to individuals on non-rotated teams. Implications for research are discussed.

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1.0 EXECUTIVE SUMMARY

Military organizations rely on teams and teamwork to accomplish complex objectives that cannot be achieved by individuals alone. Understanding how teams can be influenced and optimized are essential elements for the success of organizations within the Department of Defense (DoD). Recent literature in the teamwork domain recognizes the positive influence team training can have on team performance. What then are the most effective methods for training teams? One such method gaining esteem within the research community is positional rotation cross-training, whereby the individual members of a team are trained by performing the tasks and responsibilities of all roles within the team. The purpose of this study was to understand the influence positional rotation cross-training has on performance as well as on critical team process factors identified by previous research. Those factors include collective efficacy, communication, cohesion, and team trust. The current study had thirty participants engage in the Distributed Dynamic Decision-making (DDD) air defense command and control (C2) simulation, and employed the use of self report surveys to investigate these constructs. Unexpectedly, the only construct significantly impacted by cross-training was team trust, and this impact was in the opposite direction than was predicted. Based on previous research, cross-training was hypothesized to be positively correlated with team trust, but it proved to be a hindrance to the development of trust for the teams of this study. Several explanations exist for these results including the limitations of this experiment, and are discussed along with implications for the direction of future research.

2.0 INTRODUCTION

Issues regarding teamwork have been a topic of focus within the research community for the last several decades. Military organizations use teams to accomplish complex tasks which are difficult, if not impossible, for individuals to perform alone. Therefore, teams comprise an essential capability within the Department of Defense (DoD) that ranges from small combat teams to large and complex command and control (C2) teams. Despite their prominence within the DoD echelons, there is still a great deal to learn about team effectiveness. Often times, high profile accidents are attributed to breakdowns in team processes, such as the shooting down of Iran Air flight 655 by the USS Vincennes (Johnston, Cannon-Bowers, & Salas, 1998). In this case, a military C2 team operating under high stress mistakenly identified a passenger plane as a hostile aircraft and engaged it with lethal force. Nearly 300 people perished. These breakdowns of team process can be catastrophic for military operations given the high operations tempo and dangerous mission environments that the DoD typically operates within. Thus, generating effective and efficient teamwork is imperative for the DoD.

Most team taxonomies involve an Input-Process-Output (IPO) paradigm that generates considerations for team inputs, team processes, and team outcomes (Kozlowski & Bell, 2003). Team inputs can include variables that range from the personality of its members to team composition factors (e.g., team size, diversity). Team process variables often revolve around issues of communication, cohesion, and trust. Finally, a typical team outcome variable of interest to researchers is team performance. Considering the IPO paradigm, the current study sought to explore the impact of team training (input) on team process variables such as collective efficacy beliefs, communication, cohesion, and trust.

2.1 Team Cross-Training

A recent review of the team literature acknowledged the powerful effect of team training on performance (Salas, Cooke, & Rosen, 2008). Meta-analytic procedures have also found that, in general, team training tends to result in enhanced team performance (Salas, Nichols, & Driskell, 2007). One such strategy involves cross-training. Cross-training represents an activity where each individual team member is trained on the tasks, duties, responsibilities, of his/her other team members (Volpe, Cannon-Bowers, & Salas, 1996). Research has shown that teams that engage in cross-training evidence better communication and team performance relative to teams without such training (Volpe, Cannon-Bowers, & Salas, 1996). There are a variety of cross-training techniques. Blickensderfer et al., (1998) discussed three types of cross-training: positional clarification, modeling, and rotation. Positional clarification involves the verbal or written presentation of the roles and activities of the team. Positional modeling involves both the presentation of role information as well as the observation of the activities through either live modeling or video presentation. Finally, positional rotation occurs when team members actually participate in the different roles within the team.

Cross-training may help team members to anticipate the information needs of their teammates (Volpe, Cannon-Bowers, & Salas, 1996). This anticipation of other's needs may promote trust and cohesion within the team as teammates begin to establish common ground and shared understanding of the task and the context. Further, research has shown that cross-training results in the development of shared mental models, and that the relationship between shared mental models and team performance is mediated by coordination (Marks, Sabella, Burke, & Zaccaro, 2002). Thus, cross-trained teams perform better due primarily to enhanced communication, a critical team process factor. Communication is also critical to developing trust, thus it is plausible that cross-trained teams might also develop higher trust relative to non-cross-trained teams, particularly as the members of the team interact over time. Because cross-training tends to result in higher team performance, it is logical that cross-training will also positively impact collective efficacy perceptions within the team.

2.2 Collective Efficacy

Self-efficacy represents the belief that one possesses the ability to meet the demands of a specific situation (Bandura, 1997). These perceptions can have an individual focus where one evaluates his or her own abilities, or they can have a team focus where individuals evaluate the ability their team to accomplish some goal. The latter is referred to as collective efficacy. Past research has shown that collective efficacy can be shaped by leadership (Walumbwa, Wang, Lawler, & Shi, 2004) and is thus malleable. Additionally, research has shown that when individuals are oriented toward learning they report higher efficacy during task situations (VandeWalle, Cron, & Slocum, 2001). Cross-training is an example of a learning-oriented activity and may promote the development of collective efficacy.

2.3 Communication

As the information complexities of modern warfare create heightened demands on military teams, information exchange between military operators remains to be a cornerstone of current and future military teams (Alberts & Hayes, 2003). Research has shown that high-performing teams tend to optimize information exchange (Aubert & Kelsey, 2003). Taxonomies of team adaptability emphasize that communication is critical to team performance and adaptability (Burke, Stagl, Salas, Pierce, & Kendall, 2006). Communication represents the mechanism through which team members interact, and team training may be used to influence how team members interact and communicate. Previous research has found that cross-training results in enhanced coordination (Marks, Sabella, Burke, & Zaccaro, 2002), and it was an expectation of this study to find that cross-training has a similar effect on communication.

2.4 Cohesion

Another relevant team process variable is cohesion, which can be thought of as the attraction of the team members toward the group. Cohesion has been linked to lower team conflict and higher satisfaction with the team (Kozlowski & Bell, 2003). Meta-analytic

procedures have evidenced a small but positive relationship between cohesion and performance (Mullen & Cooper, 1994). Cohesion is socially-oriented, thus the socialization of team members with one another may impact the degree to which the team develops cohesion. Team training techniques may reduce team conflict by establishing team norms, performance expectations, and feedback mechanisms. Cross-training may enhance team cohesion because of the shared understanding that develops within the team during cross-training activities. This shared understanding may help the team to establish a common ground for handling conflict, giving feedback, and managing performance expectations. These factors should, in turn, promote higher cohesion.

2.5 Team Trust

Research on team trust has burgeoned in recent years, likely due to the changing nature of work in an age of information. Information technologies and information exchange have become increasingly important success factors of contemporary organizations. The willingness to share information and the ability to convince others to provide information are key elements that may distinguish between high and low performers, and these elements are dependent on the construct of trust. Generally, trust represents the willingness of an individual to accept vulnerabilities from others (Mayer, Davis, & Schoorman, 1995). There are three fundamental aspects of trust. First, trust is relational. Trust is only relevant in the context of a relationship between two or more entities. These relationships may constitute interpersonal relations (Mayer, Davis, & Schoorman, 1995) or interactions between a person and an information technology system (Lee & See, 2004). Second, trust is dynamic and changes over the course of an interaction. Research has shown that the predictors of trust change over the course of an interaction with dispositional factors influencing trust early and indicators of trustworthiness influencing trust latter in the process (Levin, Whitener, & Cross, 2006). Finally, trust is only relevant in the context of risk. If there is no risk in a situation then trusting others is irrelevant. One example could be the trust one places on a weather forecast for a geographic area where one has no specific ties (e.g., no plans to visit or no ties to people that live in that area).

Past research has found that trusting teammates may reduce the costs associated with monitoring personnel (Aubert & Kelsey, 2003), promote a collective rather than an individual orientation (Dirks, 1999), and facilitate information sharing in team contexts (Kimmerle, Cress, & Hesse, 2007). Thus, trust is a highly relevant team process to facilitate within a military operational team. Recent meta-analytic data supports a positive relationship between trust and task performance and helping behavior (Colquitt, Scott, & LePine, 2007), both of which are relevant within military teams as well.

We can conclude that trust is an important element of military teams. However, the question of how trust can be fostered within military teams remains. Past research has indentified various indicators of trustworthiness in interpersonal relationships, including: ability, benevolence, and integrity (Mayer, Davis, & Schoorman, 1995). According to these three

indicators of trustworthiness individuals may be trusted more when they possess high ability, are perceived as having benevolent intentions, and when they are thought to have high integrity. Perceptions of trustworthiness are shaped over time (Levin, Whitener, & Cross, 2006), and thus is plausible that the type of training a team engages in will impact how those individuals develop trust.

2.6 Purpose and Hypotheses

The overall objective of the present study was to explore the impact of cross-training on team processes over time. It was expected that the members of teams engaged in cross-training would report higher collective efficacy, communication, cohesion, and trust of their teammates relative to individuals on teams that did not engage in cross-training.

3.0 METHOD

3.1 Participants

One hundred and five participants completed the experiment in five-person teams producing a total of 21 experimental teams. The composition of participants was 71% men, and 29% women ranging in age from 18 to 30 (M = 21.94, SD = 3.16). The study discussed in this report focused on a subset of this larger group and was comprised of thirty participants yielding six experimental teams (3 cross-trained and 3 not cross-trained). Prospective participants were recruited from both a temporary work agency and from local universities. Potential participants were screened using a biographical survey and the letter-sets test (Ekstrom et al., 1976). Those who were selected for inclusion and partook in the study were monetarily compensated for their contributions.

3.2 Design

This study employed a one factor repeated measures design conducted simultaneously within the scope of a larger factorial study. The factor of interest for this study was team rotation. Within this factor, teams were randomly assigned to either one of two treatment conditions (permanent or rotated) and participants were randomly given an initial assignment to one of three roles (weapons director, strike operator, tanker operator) within each team. Members of teams receiving the permanent treatment condition maintained constant roles throughout the entire experiment. In contrast, members of the rotation team condition rotated into new roles within their team for each new data collection session. The team rotation factor was used to evaluate the effect role rotation within teams has on task performance as well as on team social constructs including collective efficacy, communication, cohesion, and trust.

3.3 Materials

Apparatus. This experiment employed the DDD simulated air defense C2 software version 3.0 running in the Linux environment. This software has been used in a multitude of previous experiments and has been rigorously demonstrated to be sensitive to experimental manipulations. Specifically within the DDD platform, participants were engaged in the *Tanker* scenario which is a five person air battle management command and control simulation. In this tactical C2 simulation, teams comprised of two weapons directors (WD's), two strike operators (SO's), and one tanker operator (TO) are responsible for the coordination of offensive air-operations, defensive air-operations, and air refueling operations.

The software was deployed over five networked computer workstations set up in a climate controlled laboratory to simulate an arrangement normally found on an airborne early warning and control (AEW&C) platform. Each station housed a Hewlett-Packard pc equipped with an AMD Athalon 64 X2 4800+ processor with 2 GB RAM and dual Dell 17" flatscreen LCD displays. Communication between all five team members was conducted over the same

radio channel using Sennheiser HMD 224 headsets to simulate the saturated AEW&C communication environment. To further simulate background noise conditions normally found in AEW&C operational environments, a white noise generator was employed during experimental trials.

The Tanker scenario is presented via a dynamic tactical display that presents an area of responsibility (AOR) comprised of three sensitive battle management zones that contain both friendly and enemy assets. The three battle management zones included a "preferred attack zone" where enemy assets entered the AOR, a sensitive "friendly territory," and a highly sensitive "home territory" that contains an air base and ranger units (Figure 1). The objective of each Tanker team was to defend the friendly and home territories against attacks from enemy fighter assets. This objective was met by identifying and destroying enemy assets as quickly as possible, preventing those enemy assets from entering friendly territory, protecting the air base and ranger units located in the home territory, and keeping friendly assets airborne for as long as possible through refueling and weapon resupply efforts.

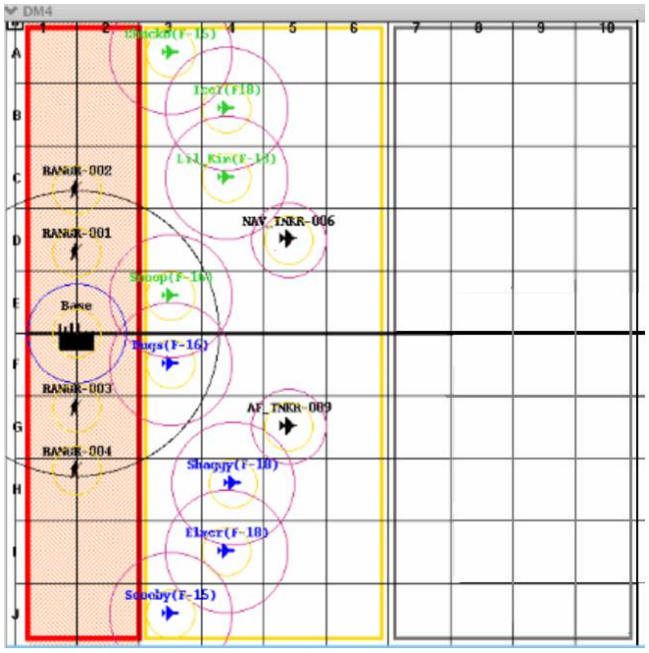

Figure 1: An Image from the Tactical Display of the DDD Tanker Scenario

Weapons directors, strike operators, and tanker operators all differ in regard to their roles and capabilities. The role of the WD is to manage the battle by directing friendly assets to appropriate enemy targets and scheduling those fighters for refueling and weapon resupply. The role of the SO is to maneuver three friendly strike fighter assets as instructed by the WD, identify and engage enemy targets, and to communicate asset resource information with the team. The role of the TO in the simulation is to maneuver two tanker assets as instructed by the WD, rendezvous with friendly assets for refueling and resupply, and to communicate asset information to the team. The Tanker task is designed to create an operational need for team

collaboration by keeping specific asset information unavailable to all team members with access to this information dictated by role within the team. For example, only tanker and strike operators had access to weapon and fuel status regarding assets assigned to them. Therefore, WD's had to rely on their teammates to communicate this resource information to them in order to adequately perform their battle management task.

Within the construct of this study, four team performance variables were measured and included a total score, an air defense score, the number of enemy assets allowed to enter into the home battle management area, and the average duration in time between when an enemy asset was identified to when it was destroyed. The air defense score was a composite indicator that considered the number of fighters lost, the number of high value assets (tankers, ranger units, air base) lost, and penetration of the friendly territories by enemy assets. The team total score was also a composite indicator and was composed of the air defense score, additional points assessed for identifying unknown targets, and penalty points assessed for refueling using an incorrect tanker/fighter combination.

Questionnaires. Within the scope of this study, four computer-based surveys comprised of 42 assessment items were utilized to measure four distinct team constructs: collective efficacy, team communication, group cohesion, and team trust. All four surveys utilized the same 7-point Likert scale (1=Strongly Disagree, 2=Disagree, 3=Somewhat Disagree, 4=Neither Agree nor Disagree, 5=Somewhat Agree, 6=Agree, 7=Strongly Agree) that was visually displayed using a horizontal analog scale.

The survey of collective efficacy (based on Riggs & Knight, 1994) was composed of seven items that measured individual's perceptions about the abilities of their team (e.g. "The members of this team have excellent task skills"). The team communication survey was developed for the purpose of this study and contained 10 items that measured perceived communication and information sharing (e.g. "If my performance on this task is good, it's because I get the information I need from my teammates"). The Cohesion Questionnaire (Stokes, 1983) is a 13-item survey that is based on a 3-dimensional conceptualization of cohesion that includes risk-taking (e.g. "The group avoids saying anything which might upset someone"), attraction towards the group (e.g. "If I were to participate in another group like this one, I would want it to include people who are very similar to the ones in this group"), and instrumental value (e.g. "The group has influenced me in a lot of positive ways"). The team trust survey (based on Naquin & Paulson, 2003) included 11 items that measured perceptions of trust individuals have regarding the other members of their team and the quality of their teammates' performance (e.g. "I think other team members met their obligations during the task").

3.4 Procedure

Before selection for the study, potential participants were screened using a biographical survey, and the 15-item letter-sets test. These selection criteria were based upon obtaining a

sample population closely approximating the population typically found among AWE&C operators. Regarding the biographical survey, ineligibility for the study was determined by those who responded as having no college experience or no computer experience. In addition to these criteria, those that responded "yes" to color blindness were ineligible to participate due to the color coded interface of the DDD simulation software. As a test of general reasoning ability, participants completed the 15-item letter sets test. Items on this test consist of five sets of four letters (e.g. ABCD), and test takers are asked to infer the pattern contained within the letter sets then identify the set that deviates from the pattern rule. Participants were allotted seven minutes to complete the fifteen items, with eligibility for this study determined by those scoring nine or more of the fifteen items correctly.

Upon arrival at the laboratory, participants completed an informed consent document, were introduced to their teammates and given a brief overview of the experiment by an experimenter. Participants then received computer based training in the form of a PowerPoint presentation that successively detailed the DDD tanker scenario, radio communication and controls, the team's objectives, and the responsibilities of each role within the team.

All teams included in this study completed five experimental sessions. The first experimental session was devoted to training with each of the four subsequent sessions being devoted to data collection. Each experimental session was approximately eight hours in duration and contained an ordered series of computer based training, experimental trials, questionnaires, performance feedback, and structured team discussions. Each data collection session contained 16 experimental trials of the DDD Tanker scenario that were ten minutes in duration. The schedule of experimental conditions was counterbalanced across teams to control for order effects. At the conclusion of each experimental session, participants completed a series of questionnaires that included the four team social construct surveys utilized for this study.

4.0 RESULTS

Means and standard deviations for all study variables are presented in Table 1. Repeated measures Analysis of Covariance (ANCOVAS) were used to test for differences between the experimental conditions. ANCOVAs were used to control for team collective efficacy, communication, cohesion, trust during the first day. Controlling for these variables was critical because the two conditions were essentially equivalent on the first day of data collection as no team rotation had occurred yet. Relevant results would include a significant main effect of cross-training condition or an interaction of condition over time.

Table 1: Means and Standard Deviations of All Study Variables by Condition

Variable	Rotated	Permanent	Overall
Collective Efficacy T1	5.01 (.97)	5.70 (.72)	5.35 (.91)
Collective Efficacy T2	5.29 (1.30)	5.75 (.59)	5.52 (1.02)
Collective Efficacy T3	5.82 (1.16)	6.05 (.81)	5.93 (.98)
Collective Efficacy T4	5.67 (1.26)	6.16 (.80)	5.93 (1.06)
Communication T1	5.33 (.69)	5.80 (.36)	5.56 (.59)
Communication T2	5.59 (.99)	5.84 (.45)	5.72 (.76)
Communication T3	5.77 (1.11)	5.98 (.69)	5.88 (.91)
Communication T4	5.64 (.92)	5.87 (.58)	5.76 (.76)
Cohesion T1	5.74 (1.07)	5.84 (.79)	5.79 (.93)
Cohesion T2	5.91 (1.02)	5.70 (.72)	5.80 (.87)
Cohesion T3	6.02 (1.13)	5.93 (.83)	5.98 (.98)
Cohesion T4	5.90 (.92)	5.97 (.73)	5.94 (.82)
Trust T1	5.73 (.92)	6.32 (.61)	6.02 (.82)
Trust T2	5.94 (.97)	6.02 (.98)	5.99 (.96)
Trust T3	5.92 (1.10)	6.44 (.63)	6.18 (.91)
Trust T4	5.66 (1.21)	6.41 (.50)	6.03 (.98)

Note. T1 = Time 1, T2 = Time 2, T3 = Time 3, and T4 = Time 4.

Unexpectedly, the two groups did not differ on collective efficacy, group cohesion, or communication (all F's, *ns*). There were no significant main effects of cross-training nor was there a significant interaction of cross-training over time when predicting collective efficacy, group cohesion, or communication. However, there was an effect for team trust. There was a significant time by condition interaction when predicting team trust, $F(1, 27) = 7.02$, $p < .05$. As shown in Figure 2, the permanent teams unexpectedly reported higher trust overtime relative to the rotated teams.

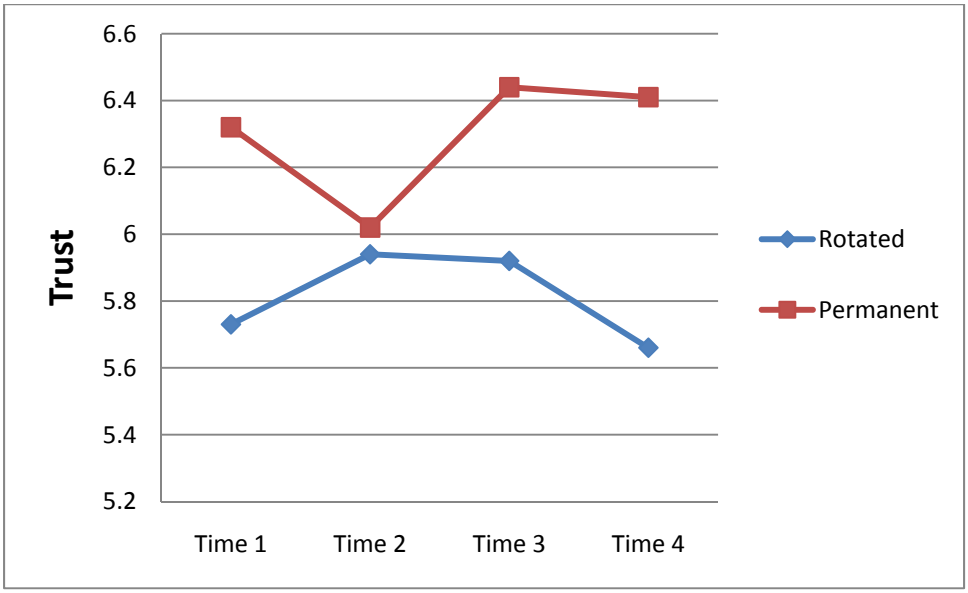

Figure 2: Time by Condition Interaction when Predicting Trust

Table 2 shows the team performance metrics by condition. It appears that the permanent teams outperformed the rotated teams according to most of the performance indicators, though readers should interpret this with caution. Given the small number of teams involved (i.e., 6) it was impossible to test for performance differences between the groups. To test for statistical differences at the team level one must use Multilevel modeling techniques which require a very large number of teams (e.g., greater than 70).

Table 2: Team Performance by Condition

Variable	Rotated	Permanent
Average Team Total Score	67.48 (19.77)	70.19 (6.24)
Average Air Defense	65.13 (17.42)	70.29 (5.87)
Number of Refuel Penalties	2 (2)	3 (1.73)
Number of Fighters Lost to Fuel Depletion	13.00 (12.28)	15.33 (11.68)
Number of Enemies in Red Zone	40.33 (24.01)	27.67 (14.29)
Average time enemy ID to enemy destroyed	134.82 (15.27)	128.34 (5.88)
Average number of correct tanker refuels	7.54 (2.21)	8.98 (2.54)
Number of platforms that land at the base	16.67 (2.08)	23.33 (4.73)

Table 3 shows correlations among all of the study variables. As shown by Table 3, many of the psychosocial variables were related to one another. There appeared to be significant overlap between variables within the same nomological network, which is to be expected. Further, there appeared to be some overlap for variables measured during the same time period. Notably, team communication was related to higher collective efficacy, group cohesion, and more trust during several different time periods.

Table 3: Correlation among All Study Variables (N = 30)

Variable	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
1. Efficacy T1	.05	.17	.34	.61**	.13	.13	.19	.62**	.12	.21	.20	.66**	.13	.31	.27
2. Efficacy T2		.36*	.19	.37*	.50**	.45*	.23	.13	.36*	.33	.32	.28	.24	.36	.16
3. Efficacy T3			.69**	.41*	.72**	.82**	.59**	.15	.54**	.58**	.43*	.31	.55**	.86**	.57**
4. Efficacy T4				.15	.38*	.45*	.79**	.01	.19	.23	.64**	.14	.31	.57**	.69**
5. Comm T1					.59**	.48**	.17	.56**	.45*	.50**	.03	.56**	.31	.53**	.17
6. Comm T2						.82**	.37*	.28	.56**	.58**	.28	.22	.46*	.74**	.36
7. Comm T3							.49**	.14	.61**	.64**	.34	.22	.55**	.84**	.46**
8. Comm T4								.01	.12	.33	.68**	.06	.21	.51**	.77**
9. Cohesion T1									.58**	.56**	.21	.63**	.20	.23	.09
10. Cohesion T2										.93**	.52**	.30	.32	.50**	.20
11. Cohesion T3											.56**	.34	.34	.61**	.29
12. Cohesion T4												.03	.13	.42*	.57**
13. Trust T1													.55**	.40*	.28
14. Trust T2														.66**	.43*
15. Trust T3															.62**
16. Trust T4															

Note. * p < .05. ** p < .01. Comm = Communications, T1 = Time 1, T2 = Time 2, T3 = Time 3, and T4 = Time 4.

5.0 DISCUSSION

The purpose of the present study was to explore how cross-training impacts the development of collective efficacy, communication processes, group cohesion, and team trust. Unexpectedly, cross-training appeared to have little to no impact on whether or not individuals reported high collective efficacy beliefs, effective team communication processes, or team cohesion. This is inconsistent with some past research which has found that cross-training facilitates team communication (Volpe, Cannon-Bowers, & Salas, 1996). However, there was a significant effect for team trust, though it was in the opposite direction than was predicted. Individuals who were on cross-trained teams reported lower trust over time relative to the individuals on permanent teams. While there was a paucity of past research in this area, we did expect that cross-training would promote a shared understanding of the task demands and anticipation of information needs within the team.

It appears in the present study, that cross-training may actually hinder the development of trust among teammates. There are three possible explanations for these findings. First, as evidenced by the performance data it appears that the rotated teams did not perform as well as the permanent teams. While it is unknown as to whether or not these performance decrements were statistically reliable or not, they may have impaired trust development within the rotated teams. In contrast, lower trust may have impaired team performance. Past research has linked trust to team performance (Colquitt et al., 2007). Future research is needed to clarify the causal relationship between trust and team performance as trust may be both an antecedent to as well as an outcome of team performance. Second, these teams interacted for a relatively short period of time. Past research has shown that computer-mediated teams develop trust slower than face-to-face teams (Wilson, Straus, McEvily, 2006), and this effect may have been exacerbated by the team rotation manipulation. It may be that in the current study the rotated team did not have enough time to calibrate to the computer-mediated nature of the communications since they were constantly changing roles. Finally, the team rotation may have impeded individuals' evaluations of trustworthiness. Past research has identified ability, integrity, and perceived benevolence as valid indicators of trustworthiness (Colquitt et al., 2007; Mayer et al., 1995). Individuals who were constantly changing roles may have had a more difficult time in establishing behavioral norms which could have reduced their ability to accurately judge trustworthiness.

Exploratory correlational analyses revealed some interesting patterns. Notably, team communication effectiveness was related to higher efficacy, cohesion, and trust at various points throughout the data collection. Past research has highlighted the importance of effective team communication in predicting team performance (Aubert & Kelsey, 2003). Effective communication may help to establish performance monitoring processes, which in turn should facilitate the development of team efficacy perceptions. Communication may also help to foster trust, as has been shown in past research (Jarvenpaa & Leidner, 1999).

5.1 Limitations and Future Research

One limitation of the current study was small sample size. The limited sample size inhibited our ability to test team-level analyses. For example, it may be that the relationship between trust and performance is actually stronger for rotated teams despite overall lower mean values for trust. That may be because the rotated teams create an inherent uncertainty that the permanent teams may not have experienced. This speculation can only be tested by looking at the relationship of trust and performance at the team level using sophisticated statistical analyses such as hierarchical linear modeling (HLM); (Hox, 2002). Such analyses offer a great deal of rigor to their findings, however, they also require very large sample sizes (e.g., seventy teams) which can be costly and time consuming. Such studies are highly difficult in military domains, particularly if one plans to use military participants. A second limitation involves the artificial time periods within which the teams interacted. The teams in the current study interacted over the course of a week (i.e., approximately four days), and while this is a very long time in experimental terms, it is actually quite brief for an operational team. Despite the brief interaction however, participants were engaged in a high-fidelity military simulator.

Future research should explore these effects using a larger sample size to allow for sophisticated statistical analyses such as HLM which will allow researchers to explore team-level phenomenon. Further, future research might consider using a combination of laboratory-based teams and actual work teams which interact over a longer time period. Studies that incorporate a longer data collection period may find that rotated teams evidence higher trust, efficacy, cohesion, and communication over the course of a team's lifecycle.

6.0 CONCLUSION

The present study investigated the effects of team cross-training on outcomes such as collective efficacy, communication effectiveness, cohesion, and trust. There are currently few studies which have empirically evaluated the impact of team cross-training on team process outcomes. Cross-training was found to impact the development of team trust but not in the direction which was predicted. Future research is warranted to further explore these effects.

REFERENCES

Alberts, D.S., & Hayes, R.E. (2003). *Power to the edge: Command control in the information age*. CCRP Publication Series.

Aubert, B.A., & Kelsey, B.L. (2003). Further understanding of trust and performance in virtual teams. *Small Group Research, 34*(5), 575-618.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman.

Blickensderfer, E., Cannon-Bowers, J.A., & Salas, E. (1998). Cross-training and team performance. In J. A. Cannon-Bowers & E. Salas (Eds.), *Making decisions under stress: Implication for individual and team training* (pp. 299-311). Washington, DC: American Psychological Association.

Burke, C.S., Stagl, K.C., Salas, E., Pierce, L., & Kendall, D. (2006). Understanding team adaptation: A conceptual analysis and model. *Journal of Applied Psychology, 91*(6), 1189-1207.

Colquitt, J.A., Scott, B.A., & LePine, J.A. (2007). Trust, trustworthiness, and trust propensity: A meta-analytic test of their unique relationships with risk taking and job performance. *Journal of Applied Psychology, 92*(4), 909-927.

Dirks, K.T. (1999). The effects of interpersonal trust on work group performance. Journal of Applied Psychology, 84, 445-455.

Ekstrom, R.B., French, J.W., Harman, H.H., & Derman, D. (1976). Manual for kit of factor-referenced cognitive tests. Princeton, NJ: Educational Testing Services.

Hox, J. (2002). *Multilevel analysis: Techniques and applications*. Mahwah, NJ: Lawrence Erlbaum Associates.

Jarvenpaa, S.L., & Leidner, D.E. (1999). Communication and trust in global virtual teams. *Organizational Science, 10* (6), 791-815.

Johnston, J.H., Cannon-Bowers, J.A., & Salas, E. (1998). *Tactical decision making under stress (TADMUS): Mapping a program of research to a real world incident-The USS Vincennes*. Paper presented at the RTO HFM Symposium on "Collaborative crew performance in complex operational systems." Edinburgh, United Kingdom.

Kimmerle, J., Cress, U., & Hesse, F.W. (2007). An interactional perspective on group awareness: Alleviating the information-exchange dilemma (for everybody?). *International Journal of Human-Computer Studies, 65*, 899-910.

Kozlowski, S.W.J., & Bell, B.S. (2003). Work groups and teams in organizations. In W. Borman and D. Ilgen (Eds.), *Handbook of psychology: Industrial and organizational psychology,* (Vol. 12, pp. 333-375). New York, NY: John Wiley & Sons Inc.

Lee, J.D., & See, K.A. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors, 46*, 50-80.

Levin, D.Z., Whitener, E.M., & Cross, R. (2006). Perceived trustworthiness of knowledge sources: The moderating impact of relationship length. *Journal of Applied Psychology, 91*, 1163-1171.

Marks, M.A., Sabella, M.J., Burke, C.S., & Zaccaro, S.J. (2002). The impact of cross-training on team effectiveness. *Journal of Applied Psychology, 87*(1), 3-13.

Mayer, R.C., Davis, J.H., & Schoorman, F.D. (1995). An integration model of organizational trust. *Academy of Management Review, 20*, 709-734.

Mullen, B., & Cooper, C. (1994). The relation between group cohesiveness and performance: An integration. *Psychological Bulletin, 115*, 210-227.

Naquin, C.E., & Paulson, G.D. (2003). Online bargaining and interpersonal trust. *Journal of Applied Psychology, 88*(1), 113-120.

Riggs, M.L., & Knight, P.A. (1994). The impact of perceived group success-failure on motivational beliefs and attitudes: A causal model. *Journal of Applied Psychology, 79*(5), 755-766.

Salas, E., Cooke, N.J., & Rosen, M.A. (2008). On teams, teamwork, and team performance: Discoveries and developments. *Human Factors, 50*(3), 540-547.

Salas, E., Nichols, D.R., & Driskell, J.E. (2007). Testing three team training strategies in intact teams. *Small Group Research, 38*(4), 471-488.

Stokes, J.P. (1983). Components of group cohesion: Intermember attraction, instrumental value, and risk taking. *Small Group Behavior, 14*(2), 163-173.

VandeWalle, D., Cron, W.L., & Slocum, J.W. (2001). The role of goal orientation following performance feedback. *Journal of Applied Psychology, 86*, 629-640.

Volpe, C.E., Cannon-Bowers, J.A., & Salas, E. (1996). The impact of cross-training on team functioning: An empirical investigation. *Human Factors, 38*(1), 87-100.

Walumbwa, F.O., Wang, P., Lawler, J.J., & Shi, K. (2004). The role of collective efficacy in the relations between transformational leadership and work outcomes. *Journal of Occupational & Organizational Psychology, 77*, 515-530.

Wilson, J.M., Straus, S.G., McEvily, B. (2006). All in due time: The development of trust in computer-mediated and face-to-face teams. *Organization Behavior and Human Decision Processes, 99*, 16-33.

LIST OF ACRONYMS

AEW&C	Airborne Early Warning and Control
ANCOVAS	Analysis of Covariance
AOR	Area of Responsibility
C2	Command and Control
DDD	Distributed Dynamic Decision-making
DoD	Department of Defense
IPO	Input-Process-Output
SO	Strike Operator
TO	Tanker Operator
WD	Weapons Director